AQA

ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark scheme January 2003

GCE

Chemistry

Unit CHM2

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SECTION A

Answer **all** questions in the spaces provided.

1 The table below contains some standard enthalpy of formation data.

Substance	C(s)	$N_2(g)$	$H_2O(g)$	$CO_2(g)$	$NH_4NO_3(s)$
$\Delta H_f^\ominus$/kJ mol^{-1}	0	0	−242	−394	−365

(a) Why are the values of the standard enthalpy of formation for carbon and nitrogen zero?

they are elements (1)

(ignore irrelevant comments)

(1 mark)

(b) State Hess's Law.

enthalpy change (1) or heat energy change or any named enthalpy change or heat change or ΔH e.g. if change not mentioned

independent of route (1)

(or depends on initial and final states)

(2 marks)

(only give second mark if first awarded except allow if energy used instead of enthalpy)

(c) Use $\Delta H_f^\ominus$ data from the table to calculate a value for the enthalpy change for the following reaction.

$$NH_4NO_3(s) + \tfrac{1}{2}C(s) \rightarrow N_2(g) + 2H_2O(g) + \tfrac{1}{2}CO_2(g)$$

$\Delta H = \sum \Delta H_f^\ominus$ (products) $- \sum \Delta H_f^\ominus$ (reactants) (1) OR cycle

$= 2 \times -242 + \frac{1}{2} \times -394 - (-365)$ (1) also implies first mark

$= -316$ kJ mol^{-1} (1)

(3 marks)

ignore no units

penalise wrong units

+316 scores 1/3

6

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2 The table below contains some mean bond enthalpy data.

Bond	H–H	C–C	C=C	N≡N	N–H
Mean bond enthalpy / kJ mol^{-1}	436	348	612	944	388

(a) Explain the term *mean bond enthalpy*.

{enthalpy Energy to break a (covalent) bond (1) or dissociation energy

varies between compounds so average value used (1) (Q.L. mark)

or average of dissociation energies in a single molecule (eg CH_4)

(do not allow mention of energy to form bonds
but in this case can allow second mark otherwise 2nd mark consequential on first.) *(2 marks)*

(b) (i) Write an equation for the formation of one mole of ammonia, NH_3, from its elements.

$\frac{1}{2}N_2 + \frac{3}{2}H_2 \rightarrow NH_3$ (1) ignore s.s.

(ii) Use data from the table above to calculate a value for the enthalpy of formation of ammonia.

score
2/3 for −76
1/3 for +38
allow 1/3 for +76

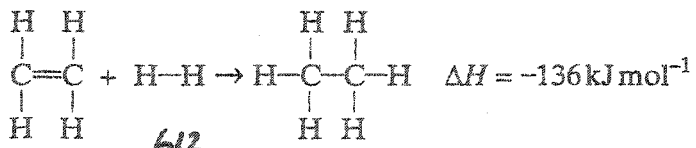
$\Delta H = (\Sigma)$ bonds broken $- (\Sigma)$ bonds formed (1)

$= \frac{1}{2} \times 944 + \frac{3}{2} \times 436 - 3 \times 388$ (1)

$= -38$ kJ mol^{-1} (1)

(ignore no units, penalise wrong units) *(4 marks)*

(c) Use the following equation and data from the table above to calculate a value for the C–H bond enthalpy in ethane.



612 436 348

$4(C\text{–}H) + (C{=}C) + (H\text{–}H) - (6(C\text{–}H) + (C\text{–}C)) = -136$ (1)

OR $(C{=}C) + (H\text{–}H) - ((C\text{–}C) + 2(C\text{–}H)) = -136$

$2(C\text{–}H) = 836$ (1)

$(C\text{–}H) = 418$ (kJ mol^{-1}) (1)

(3 marks)

Note allow (1) for −836
another (1) for −418

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Turn over ▶

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3 (a) Define the term *activation energy* for a reaction.

minimum energy (1)
required before a reaction can { occur (1) / or go / or start }

(2 marks)

(b) Give the meaning of the term *catalyst*.

speeds up (changes) reaction rate (1)
without being (chemically) { changed (1) / used up }

(2 marks)

(c) Explain in general terms how a catalyst works.

provides alternative reaction route (1)
with lower activation energy (1)

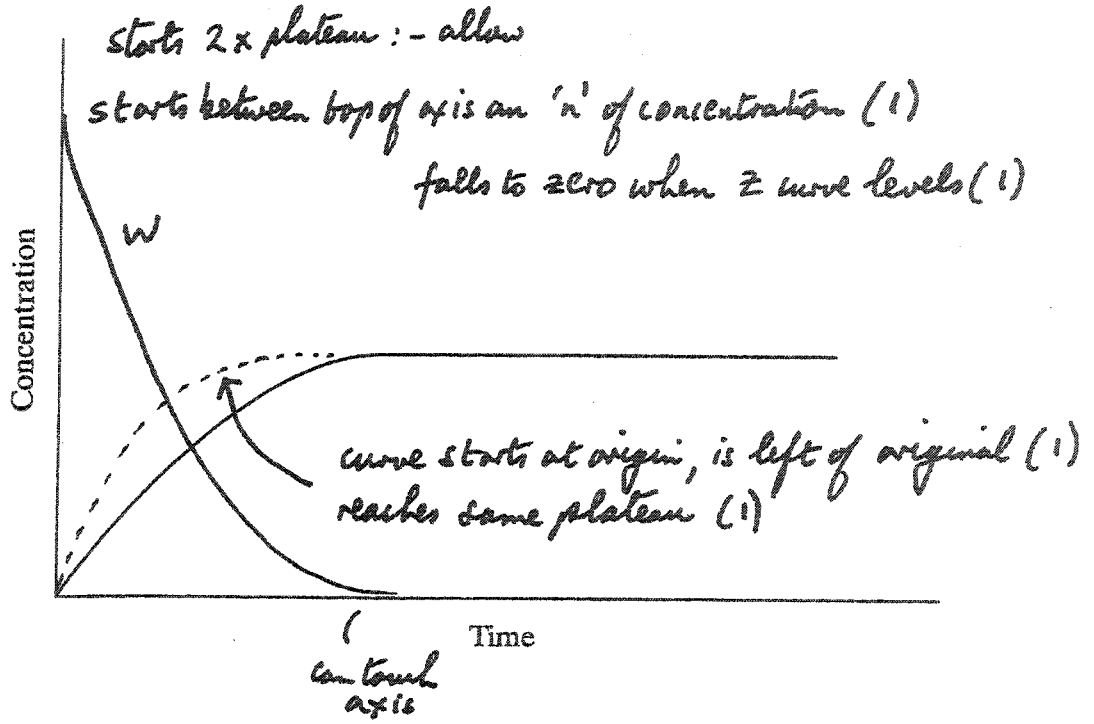
(2 marks)

word 4 words or 4 points wherever found

(d) In an experiment, two moles of gas **W** reacted completely with solid **Y** to form one mole of gas **Z** as shown in the equation below.

$$2W(g) + Y(s) \rightarrow Z(g)$$

The graph below shows how the concentration of **Z** varied with time at constant temperature.



(i) On the axes above, sketch a curve to show how the concentration of **W** would change with time in the same experiment. Label this curve **W**.

(ii) On the axes above, sketch a curve to show how the concentration of **Z** would change with time if the reaction were to be repeated under the same conditions but in the presence of a catalyst. Label this curve **Z**.

(iii) In terms of the behaviour of particles, explain why the rate of this reaction decreases with time.

fewer collisions (1)

W used up (1)
or reactants
or reagents
or fewer particles

(6 marks)

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4 Methanol can be synthesised from carbon monoxide by the reversible reaction shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91\,kJ\,mol^{-1}$$

The process operates at a pressure of 5 MPa and a temperature of 700 K in the presence of a copper-containing catalyst. This reaction can reach dynamic equilibrium.

(a) By reference to rates and concentrations, explain the meaning of the term *dynamic equilibrium*.

rate of forward reaction = rate backward reaction (1)

concentrations remain constant (1)

(NOT 'equal', allow 'the same') if clear that means 'constant' *(2 marks)*

(b) Explain why a high yield of methanol is favoured by high pressure.

fewer moles (of gas) on R.H.S. (1) (or converse)

(methanol favoured) by reducing applied pressure (1)
(or removing constraint)
≡ bwn → R *(2 marks)*

(c) Suggest **two** reasons why the operation of this process at a pressure much higher than 5 MPa would be very expensive.

Reason 1 { power / energy required to provide } { high pressure / pumping } (1)

Reason 2 strong pressure vessel (or equipment) (1) any two

high maintenance costs (1)
high insurance costs (1) *(2 marks)*

(d) State the effect of an increase in temperature on the equilibrium yield of methanol and explain your answer.

Effect decreases (1) (or reverse reaction endothermic)

Explanation reaction exothermic (1)

{ system tries to lower T (or remove constraint / or oppose the change) (1)
OR endothermic reaction favoured

(3 marks)

(e) If a catalyst were not used in this process, the operating temperature would have to be greater than 700 K. Suggest why an increased temperature would be required.

to speed up reaction (1)

(1 mark)

(OR if first mark endothermic allow reverse reaction favoured)

OR otherwise too slow
OR " takes too long
OR to give more molecules $E > E_a$

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5 (a) State and explain the trend in electronegativity down Group VII from fluorine to iodine.

Trend decreases (1) (C.E if wrong)

Explanation number of shells increases (or Atomic radius increases) (1)

(increased nuclear shielding (1)
OR less attraction for bond pair electrons)

(3 marks)

(b) (i) Describe what you would observe when an aqueous solution of bromine is added to an aqueous solution containing iodide ions. Write an equation for the reaction occurring.

Observation brown solution or black solid (1) purple wrong.

Equation $Br_2 + 2I^- \rightarrow I_2 + 2Br^-$ (1)
(allow NaI, KI)

(ii) Explain why bromine does not react with aqueous chloride ions.

Br_2 is a weaker oxidising agent than Cl_2 (1) (or converse)
OR Br_2 is less reactive than Cl_2 "

(3 marks)

penalise Cl, Br, Cl^-, Br^- etc.

(c) Describe what you would observe when aqueous silver nitrate is added to separate aqueous solutions of potassium fluoride and potassium bromide.

Observation with KF(aq) no change (1) (or colourless)

Observation with KBr(aq) {cream / off white} precipitate (or solid) (1)

(2 marks)

(d) Write an equation to show how solid potassium fluoride reacts with concentrated sulphuric acid.

$KF + H_2SO_4 \rightarrow KHSO_4 + HF$ (1) allow ions

(or $2KF + H_2SO_4 \rightarrow K_2SO_4 + 2HF$)

(1 mark)

(e) Write an equation for the redox reaction of sodium bromide with concentrated sulphuric acid.

$2H_2SO_4 + 2Br^- \rightarrow SO_2 + Br_2 + 2H_2O + SO_4^{2-}$

(2 marks)

(1) balanced equn (1)

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allow $2H_2SO_4 + 2NaBr \rightarrow SO_2 + Br_2 + 2H_2O + Na_2SO_4$

$H_2SO_4 + 2HBr \rightarrow 2H_2O + Br_2 + SO_2$ etc.

Turn over ▶

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6 (a) In acidic conditions, hydrogen peroxide, H_2O_2, oxidises iodide ions to iodine. The hydrogen peroxide is reduced to water. In H_2O_2, oxygen has an oxidation state of −1.

(i) Construct a half-equation for the reduction of hydrogen peroxide to water in acidic conditions.

$H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$ (1)

(ii) Construct a half-equation for the oxidation of I^- ions to iodine.

$2I^- \longrightarrow I_2 + 2e^-$ (1)

(iii) Construct an equation for the overall reaction.

$H_2O_2 + 2H^+ + 2I^- \longrightarrow I_2 + 2H_2O$ (1)

allow 2HI

(3 marks)

(b) The concentration of an aqueous iodine solution can be determined by titration with aqueous sodium thiosulphate. In a titration, 25.0 cm^3 of an aqueous iodine solution reacted with exactly 19.5 cm^3 of a 0.120 mol dm^{-3} solution of sodium thiosulphate.

(i) Write an equation for the reaction between iodine and thiosulphate ions.

$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$ correct formulae of reactants & products (1) balanced (1)

allow Na^+ wherever

(ii) Calculate the concentration of the iodine solution.

(If you are unable to answer part (b)(i), assume that one mole of iodine reacts with three moles of thiosulphate ions. This is not the correct ratio.)

allow conseq on wrong equation

moles thiosulphate $= \frac{19.5}{1000} \times 0.120 = 0.00234$

moles iodine $= \frac{\text{moles thio}}{2}$ (1) $= 0.00117$ (1)

moles iodine in 1000 $cm^3 = 0.00117 \times \frac{1000}{25} = 0.0468$ (1)

allow 0.0466 to 0.047(0)

(5 marks)

(if use 3:1 moles $I_2 = \frac{\text{moles thio}}{3}$ (1) $= 0.000780$

moles I_2 in 1000 $cm^3 = 0.000780 \times 40 = 0.0312$ (1)

allow 0.031(0) – 0.314)

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(c) Chlorine reacts with water as shown in the following equation.

$$Cl_2 + H_2O \rightleftharpoons Cl^- + HClO + H^+$$

In this reaction, chlorine acts both as an oxidising agent and as a reducing agent.

(i) Construct a half-equation for the reduction of chlorine to chloride ions.

$Cl_2 + 2e^- \rightarrow 2Cl^-$ (1)

(ii) Deduce the oxidation state of chlorine in HClO.

+1 (1) allow 1, 1+, Cl^+

(iii) Construct a half-equation for the oxidation of chlorine, in reaction with water, to form HClO and H^+ ions.

$Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$ (1)

(iv) Give **one** reason why chlorine is used in the water industry.

kill bacteria } (1)
germs
microorganisms
bugs

allow sterilise
disinfect

(NOT allow purify, safe to drink)

(4 marks)

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TURN OVER FOR THE NEXT QUESTION

CHM2 January 2003 Q7 Marking scheme (post standardising)

(a) (TiO_2) treated with Cl_2 (1) *(Note, if other incorrect reagents mentioned lose one mark for*
and C(coke) (1) *(each wrong reagent after 2 marks scored up to max –2)*
at high temperature (1) *(If specific temperature mentioned allow between 500 and 1000 °C)*
$TiCl_4$ formed (1)
$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$ (1) *(Note equation can also score C, Cl_2 and $TiCl_4$ marks)*
(or $TiO_2 + C + 2Cl_2 \rightarrow TiCl_4 + CO_2$)

($TiCl_4$ reacted with) Na (or Mg) (1)
under argon (1)
$TiCl_4 + 4Na \rightarrow 4NaCl + Ti$ (1) *(Note this equation also scores the Na mark)*

Energy for TiO_2 conversion into $TiCl_4$ expensive (1) , or have to be produced first.
Raw materials in reduction of $TiCl_4$ expensive (or Na or Cl_2 expensive) (1)
Precautions to keep $TiCl_4$ dry (or to prevent hydrolysis) expensive (1)
Batch process (expensive) (1)

Max 11

(b) (In Blast Furnace) add limestone (or $CaCO_3$) (1)
$CaCO_3 \rightarrow CaO + CO_2$ (1) *(or 2 marks for combined equation $CaCO_3 + SiO_2 \rightarrow CO_2 + CaSiO_3$)*
$CaO + SiO_2 \rightarrow CaSiO_3$ (1) *(limestone mark can be scored in an equation)*
Forms slag (1)

In BOS converter main impurities in iron are:
C (1)
P (1)
S (1) *(Note that these marks can be scored in the equations)*

S removed using Mg (1)
$Mg + S \rightarrow MgS$ (1)

Oxygen (used to remove C, P) (1) *(Air not allowed)*

$C + O_2 \rightarrow CO_2$ (1) *(or $2C + O_2 \rightarrow 2CO$)*
$P_4 + 5O_2 \rightarrow P_4O_{10}$ (1) *(or $4P + 5O_2 \rightarrow 2P_2O_5$)*

Limestone (or CaO) added (1)
Oxide converted into slag (1) *(or equation between P_4O_{10} and CaO scores both marks)*

Max 13

(c) Iron scrap must be <u>separated</u> from other metals etc (1)
Using a magnet (or using magnetic properties) (1)
It is then melted down (to convert into steel) (1)
And also used in BOS process (1)

Use of scrap requires less energy than extraction (1)
Because has higher iron content than ore OR scrap does not deplete native ore reserves (1)
Scrap removed from countryside *(or any environmental issue e.g. mining but not greenhouse effect)* (1)
Less CO_2 released into atmosphere (hence greenhouse effect) (compared with extraction) (1)

<u>Max 6</u>
<u>30</u>